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XII. *The State of the Tides in Orkney; by
Mr. Murdoch Mackenzie.*

Read May 25.
1749.

NO Accounts of the Flux and Reflux of the Sea were satisfactory, till Sir *Isaac Newton's* penetrating Genius deduced their true Cause from the Laws of Gravitation. His Principles carried such Conviction along with them, and gave such an easy Solution of some of the most remarkable *Phænomena*, that Mankind seemed to imagine a thorough Knowledge of the Tides might be obtained from an attentive Consideration of the Principles he had established, without the Trouble of further Observations; but, as he, and all Philosophers since his Time, have consider'd only, or principally, the Influence of the Moon in elevating or depressing the Tides; their several Directions, Velocities, and other Affections, resulting from the Influence of Land, Shoals, and Winds, remain still as inexplicable, and as little known as ever.

As a distinct Knowledge of these Things is not only conducive to the Advancement of Science, but would greatly contribute to a convenient and safe Navigation, it may not be unacceptable to communicate such Remarks on the Tides about the *Orkney* Islands, as came under my Observation, while I was employed in surveying and navigating that and other adjacent Places; hoping it may incite others to explore the various Motions of that Element, on which such a considerable Part of the World are daily employed, in a more extensive and accurate manner than has yet been done.

From

From some Observations on the Tides in *Orkney*, I incline to think the Water begins to rise and fall sooner near the Shore than at a Distance from it.

When Spring-Tide is at its greatest Altitude, or Depression, the Water continues in a quiet State near half an Hour: Neap-Tides continue so about an Hour and a half.

The Motion of the Water, both in Ascent, Descent, and Progression, is accelerated from the first to the fourth Hour, commonly; from the fourth to the last Hour its Velocity diminishes. This, however, admits of some Variation from the Influence of Winds.

The greatest Spring-Tides, and least Neap-Tides, are commonly on the third or fourth Day, after the Syzygies and Quadratures; but in this also the Winds have a considerable Influence; West and South west Winds making the greatest Floods, and least Ebbs; North and North east Winds, on the contrary, making the greatest Ebbs and least Floods in *Orkney*, and on the North Coast of *Scotland*. When Flood-Tide is raised higher than ordinary by Winds, the subsequent Ebb is not so low as it would have otherwise been. When a high Flood is raised by the Moon, the succeeding Ebb is proportionally low.

Ordinary Spring Tides rise 8 Feet perpendicular, ordinary Neap Tides $3\frac{1}{2}$; extraordinary high Spring-Tides rise 14 Feet; extraordinary low, only 5; extraordinary high Neap-Tides rise above 6 Feet; extraordinary small Neap-Tides not above 2. Low-water Neap Tide, at a mean, I judge is about 3 Feet above Low water Spring-Tide, and High-water Spring-Tide about 3 Feet above High water Neap-Tide: Yet the
Rise

Rise and Fall vary so much, that it would require a longer Course of Observations than I have had Opportunity of making, to determine what is most frequent in this Case.

When a Stream of Tide is interrupted by Land, or Rocks, or is confined within a Chanel, or long Arm of the Sea growing uniformly narrower, the Water will rise higher there than in neighbouring Places, where it is not so affected. If the Chanel, or Arm of the Sea, has several Windings, or Reaches, as they are called in the *Thames*, the superior Elevation will not be so considerable.

The following Observations of the Rising and Falling of the Water, were made in the Day-time, in the Bay of *Kirkwall*, anno 1748.

August 8. Wind W. a Breeze.

Lait Quarter 4th Day.

Moon's Apogee distant 24° .

Moon's Declination 27° N.

Moon bearing at first W. by N.

		Feet	Inch.
The Water rose	1 st Hour	0	$\frac{1}{2}$
	2 ^d	0	2
	3 ^d	0	$4\frac{1}{2}$
	4 th	0	$9\frac{1}{2}$
	5 th	0	$5\frac{1}{2}$
	6 th and to the End	0	$5\frac{1}{2}$
		<hr/>	
		In all	2 5
		<hr/>	

August

[152]

August 15, Wind ENE. small Breeze.

New Moon 3d Day.

Moon's apparent Distance 65° .

Moon's Declination 7° S.

Moon bearing SSE.

			Feet	Inch.
The Water fell	1 st Hour	.	0	$1\frac{1}{2}$
	2 ^d	.	0	$4\frac{1}{2}$
	3 ^d	.	1	4
	4 th	.	1	8
	5 th	.	1	5
	6 th	.	0	10
			<hr/>	
In all			5	9
			<hr/>	

August 23, Wind W. almost calm.

First Quarter, 3d Day.

Moon's Perigee distant 13° .

Moon's Declination 25° S.

Moon bearing E by N.

			Feet	Inch.
The Water rose	1 st Hour	.	0	6
	2 ^d	.	1	0
	3 ^d	.	1	8
	4 th	.	1	0
	5 th	.	0	8
	6 th	.	0	7
			<hr/>	
In all			5	9
			<hr/>	

Aug. 29, Wind Sb W. Breeze at first, afterwards calm.

Full Moon 3d Day.

Moon's Perigee Dist. 68° .

Moon's

Moon's Declination 6° N.

Moon bearing NNW.

				Feet	Inch.
The Water fell	1 st Hour	.	.	1	0
	2 ^d	.	.	0	10
	3 ^d	.	.	1	4
	4 th	.	.	1	2
	5 th	.	.	2	10
	6 th	.	.	1	0
				<hr/>	
In all				8	5
				<hr/>	

Aug. 27, Wind W S W. a small Breeze, the Day of Full Moon, Moon's Perigee Distance 36° , Decl. 4° S. bearing NNW. the Water fell in all 8 Feet 4 Inches perpendicular.

Aug. 30, calm, 4th Day after Full Moon, Perigee Distance 80° , Decl. 13° N. Moon bearing N 6 W. the Water rose 8 Feet 3 Inches.

Sept. 3, Wind S W. a small Breeze, first Day of the last Quarter, Apogee Dist. 50° . Decl. 27° N. Moon bearing W. the Water rose 6 Feet 1 Inch.

Sept. 6, Wind E. a small Breeze, 4th Day of the last Quarter, Apogee Dist. 15° , Decl. 21° N. Moon bearing W. the Water rose 3 Feet 9 Inches.

Sept. 15, Wind S. a moderate Breeze, 5th Day after New Moon, Perigee Dist. 80° . Decl. 24° S. Moon bearing S by E. the Water fell 5 Feet 9 Inches.

To ascertain all the Varieties in the rising and falling of the Water, the Observations ought to have been continued much longer, the Night-Tides as well as Day-Tides observed; also the exact Times of

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the Beginning and Ending of each, the Strength of the Wind and Weight of the Atmosphere by a Barometer.

The foregoing Articles relate to the Rising and Falling of the Water; the following to the various Motions of the Stream, and their Consequences.

On the Coast of *Orkney*, and *Fair Isle* of *Sketland*, the Body of the Flood comes from the North-west; on the East and West Coasts of *Lewis*, one of the Western Isles of *Scotland*, it comes from the South.

A League or two off the Coast, the Strength of the Stream is scarce sensible, except when it is confined by Land, or near Rocks or Shoals.

When the Tide begins to rise or fall on the Shore, about that same time the Stream near the Shore begins to turn or reverse its Direction, a few Irregularities excepted.

The Stream of Tide changes its Direction sooner near Land than at a Distance from it; insomuch that, in a Place two or three Miles from Land, the Turning of the Tide is two Hours, or more, later than on the adjacent Shore: At intermediate Distances the Streams turns at intermediate times. Hence a Vessel may find a favourable Tide near Land, while it would be against her a Mile or two from it; and the contrary.

During the Continuance of Flood, the Stream varies its Direction gradually from the East toward the South, and the Stream of Ebb from the West towards the North: That is, if the Stream, when it becomes first sensible, runs East, at the latter End of
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the Tide it will run South, if the Proximity of Land or Shoals does not hinder this Change of Direction.

The greatest Velocity of Spring-Tide in *Orkney*, in the Channels where it runs quickest, is about 9 Miles an Hour: The greatest Velocity of Neap-Tide is about one third or fourth of Spring-Tide. The Tides are most rapid commonly between the third and fourth Hour. Spring-Tides acquire a considerable Degree of Strength in less than one Hour after their quiescent State begins; Neap-Tides are hardly sensible in two Hours after.

In similar Streights or Channels, lying in the same Direction, and supplied from the same Part of the Ocean, the Velocity of the Streams will be in the direct *Ratio* of the Breadth of the Inlets, and the Inverse of the Outlets.

If a Sound, or Streight between two Islands, or Continents, lies in the Direction of the main Body of the Tide, the Velocity of the Stream in that Streight will be greater (all other things alike) than in any other adjacent one, not lying in that same Direction.

If an Island lies directly in the Tide-way, the Stream will divide, or split, before it reaches the Island, into two Branches, one of which will run toward one Side or End of the Island, and the other toward the other End of it; and, in passing by, will be reflected a little from the Land. Hence a Vessel, in a Calm, carried along with a strong Stream of Tide, is in no Danger of touching an Island, or visible Rock, if the Water is deep enough near them.

If the Tide runs stronger, or more obliquely, by one End of an Island than the other, from the strongest Stream, and from the most oblique, there will be a

languid Current toward the other ; that is, the Tide, along that Side of the Island, will set longer one Way than the other.

If a strong Stream of Tide runs across the Mouth of a Bay that does not reach far into the Land ; within that Bay there will be a slow Stream setting the contrary Way. Or, if a strong Stream sets directly, or nearly so, along the Extremity of a Point, or Promontory, that stretches strait out from the Coast, between this Stream (before it reaches the Point) and the Coast, there will be a languid Current with a contrary Direction. By attending to this, one Vessel may keep her Course, or gain a Port, while another is carried away with the Tide.

If a small Island lies thwart a Tide-way, that Part of the Stream which runs along one End of it, will join what runs along the other, at some Distance beyond the Island, inclosing between them a curved Space, within which there will either be no sensible Current, or a slow one, contrary to the other Streams. The counter Current, in the middle of this almost stagnant Space, or Eddy, when it gets near the Island, splits in two ; one Branch of which runs towards one Extremity of the Island, the other towards its other Extremity ; where meeting the stronger direct Streams that form the Eddy, are by them again carried towards its *Vertex*.

These Eddies may be of great Service to Ships or Boats, by sheltering them from a rapid Stream, or even carrying them against it ; or may enable them to cross it with more Advantage, according to the different Places to which they are bound. The Opposition of the contrary Tides
bounding

bounding the Eddy, makes that Part of the Sea rougher in blowing Weather, and of a darker Colour in Calms, than the rest, by which the Limits and Direction of these Eddies are always distinguished.

The Collision of the opposite and oblique Streams, near the Ends of the Island, will excite a circular Motion in the Water, and; if the Celerity of the Tide is considerable, will occasion Whirlpools, or Cavities in the Sea, in Form of an inverted Bell, wide at the Mouth, or at the Surface of the Sea, and growing gradually narrower toward the Bottom: Their Width and Depth are in proportion to the Rapidity of the Streams that cause them, and are sometimes so large as to be dangerous. Those in *Petland Firth*, near the Islands *Stroma* and *Swona*, may, with Spring-Tide, turn any Vessel quite round, but are never so large as to endanger one otherways: There have been Instances, however, of small Boats dropping into, and being swallowed up by them. The *Hiatus*, or Cavity, is largest when it is first formed, and is carried along with the Stream, diminishing gradually in Dimensions as it goes, until it quite disappears. The Suction, or spiral Motion communicated to the Water, does not seem to extend far beyond the *Hiatus*. I passed, in a Boat, within 20 Yards of one, without being sensible of any Attraction; but indeed it was toward the latter End of the Tide, when its Strength was much abated: The Diameter of the Cavity, at that time, I judged to be between two and three Feet. When Fishermen are aware of their Approach toward a Whirlpool, or Well, as it is called in *Orkney*, and have Time to throw an Oar, or any other bulky Body into it before they
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are too near, the spiral Motion is interrupted, and the Continuity of the Water broke; which, rushing in on all Sides, immediately fills up the Cavity, and enables them to go over it safe. Hence in blowing Weather, or when there is a breaking Sea, tho' there may be a circular Motion in the Water, there can be no Cavity.

When there is a steep sunk Rock near the Concourse of such strong Tides, and not very deep below the Surface, a most amazing *Phænomenon* will happen: For, the Stream being interrupted in its Course, and falling suddenly over the Rock, is reflected from the Bottom upwards, swelling and bubbling on the Surface like boiling Water, and carrying Sand, Shells, Fishes, or other loose Bodies along with it; which, with Boats, or whatever else is near, are driven with great Force from the Center all around toward the Circumference, upon which, a Gyration of the Water ensuing, a Whirlpool begins, which is carried along with the Stream, as was said above, lessening gradually till it is quite extinguished: In a little time a new Eruption and Ebullition, like the former, begins, which proceeds in the same manner, till the Swift-ness of the Stream abates, or the Tide rises or falls too much above the Rock.

Queries concerning the Tides in a large Ocean; which, if resolved from Observation, would render the Theory more perfect.

1. Since the Attraction of the Moon raises the Water directly below her, by diminishing its Gravity toward the Earth's Center, and, at that very
same

same time, depresses it at a Quadrant's Distance, by augmenting the Gravity there, so that the superior Altitude of one Part of the Ocean is immediately balanced by the superior Gravitation of another; do not, therefore, the Tides in the Ocean rise and fall without any progressive Motion, or sensible Velocity? And do not all Currents, or Streams of Tide (not caused by Winds) proceed from the Interruption which Land, or Shoals, give to the undulatory Motion which must accompany the perpendicular Ascent or Descent of the Fluids?

2. Is it agreeable to Observation, that the Power of the Sun and Moon together, raises the Tides within the Tropics about 14 Feet, as *Newton*, *Halley*, and *Maclaurin* suppose? And how high are the Tides found to rise in Parts of the Ocean of a greater Latitude? If the Water does not rise and fall so much within the Tropics, as in Places more distant from the Equator, what hinders the greater Power to have a greater Effect? For the Moon must act with greatest Force on those Parts to which she is vertical.

3. If the Times of high and low Water depend on the Moon's Appulse to the Meridian, is it not high or low Water in all Parts of the Ocean, under the same Meridian, about the same time? And is the Difference of the Times, in Places under different Meridians, in any certain Proportion to their Difference of Longitude?

4. Since the Power of the Moon to raise the Tide in any Place is greatest when she is nearest the Zenith, it is agreeable both to Observation and Theory, that the Water rises and falls more when she is above, than when below the Horizons of Places on the same
Side

Side of the Equator with her; and the contrary: Are not the Tides also of longer Duration in that Case? Since a greater Portion of the Hemispheroid, into which the Sea is formed by the Moon's Attraction, is then above the Horizons of these Places, than is below them. If this is found to be Fact, it will also be found, that the Duration in different Places (other things alike) will be in some measure proportional to their Latitudes, and the Declination of the Moon.

5. In an oblique Sphere, all Azimuth Circles cut the Equator and its Parallels obliquely; and therefore the Moon must come sooner to, or from, a given Azimuth, with one Declination than with another. In some Latitudes this Difference will amount to several Hours. Is it not then a false Rule to judge of the Times of high or low Water by the Moon's Azimuth, or to signify one by the other, as is the Custom of Sailors?

XIII. *Some Account of the Remains of John Tradescant's Garden at Lambeth; by Mr. W. Watson F. R. S.*

Read May 25. 1749. UPON a Visit made to Mr. *John Tradescant's Garden at South Lambeth, May 21, 1749.* by Dr. *Mitchell* and myself, were observed the under-mention'd exotic Plants.

This Garden was planted by the above-mention'd Gentleman about an hundred and twenty Years since, and was, except that of Mr. *John Gerard*, the Author of